

Nanotechnology at NASA: Molecules to Missions

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Nanotechnology, the construction and utilization of functional structures with at least one characteristic dimension measured in nanometers, is anticipated by many to underlie the next revolution in materials, devices and systems. The manipulation of nanoscale elements allows direct control of the underlying quantum mechanical properties, enabling broader tailoring of the macroscopic properties of artificial materials, devices and systems. Nanotechnology is anticipated to provide needed solutions for many of NASA's unique challenges associated with human and robotic space exploration.

First, NASA has extreme materials challenges in terms of size and strength per mass. To detect and characterize objects at vast distances, ultra large apertures of 50 m and greater diameter are needed to collect sufficient light. Implementing such large structures in conventional materials technology would result in enormously heavy objects, and the cost to lift them above the Earth's atmosphere would be prohibitive. Bulk structural materials for launch vehicles, spacecraft and in situ exploration systems must be similarly reduced in mass to achieve affordable space exploration. A particular challenge is materials for vehicles designed to transport human passengers through space, or house them in environments outside the safe haven of Earth's biosphere. Nanoengineered materials promise the factors of a hundred and greater in strength per mass over conventional materials. Structural elements made of such materials could be simultaneously tailored for desired mechanical, thermal, electrical and optical properties based on the particulars of the underlying nanoscale design.

Future human and robotic space exploration will also require levels of artificial intelligence and autonomy that are not achievable with conventional information processing technologies. Nanotechnology, in combination with breakthroughs in bio and information technologies, may make this feasible. For example, quantum computing, based on the use of nonlocal, nonclassical, quantum entanglement is predicted to solve relevant hard problems, such as complex scheduling and planning, for which conventional computing systems are impractically slow and power hungry. Emerging capabilities in nanotechnology will soon allow this theoretical prediction to be implemented in nano devices in which the quantum properties of nature may be directly accessed and exploited in this manner.

As humans venture ever farther into space, other unique challenges will surface. For example, astronauts on a multi-year roundtrip expedition, are, by definition, years from the nearest Earth-side hospital for much of their journey. This places staggering demands on our ability to monitor and preserve human health and performance in environments that are known to have potentially deleterious physiological effects. Conventional biomedical approaches will not provide the desired degree of medical autonomy. Advances in biomolecular nanotechnology offer hope that health monitoring, detection of incipient problems at the earliest stage, and automated therapeutic intervention may all be achieved with molecular-scale artificial analogs to the human immune system, specifically designed to counter problems associated with exposure to the space environment.